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POLISHING PAD, PROCESS FOR PRODUCING THE SAME, AND METHOD OF POLISHING

[研磨パッド、その製法及び研磨方法]

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[Detailed Description of the Invention]

[Technical Field]

The present invention relates to a polishing pad for use in the step of planarizing non planar steps on the surface of a wafer for creating a semiconductor integrated circuit by a chemical mechanical polishing process, a method of producing thereof, and a method of polishing using the pad.

[Background Art]

A process for manufacturing a semiconductor integrated circuit includes a process of creating a conductive film on the surface of a wafer and then forming a wiring pattern by photolithography and etching, and a process of forming an interlayer insulation film on said wiring pattern. Through these processes, a non planar part consisting of a conducting material and insulating material on the surface of a wafer. In recent years, as miniaturization and multi-layering of a wiring pattern are in progress for the purpose of attaining higher density of a semiconductor integrated circuit, a technique for planarizing a non planar part on the surface of a wafer has become important so as to secure the depth of focus during the photolithography step.

As a method for a planarizing non planar step on the surface of a wafer for creating a semiconductor integrated

circuit, currently the chemical mechanical polishing (hereafter referred to as "CMP") is mainly used. The CMP method is a method involving the use of a processing liquid (hereinafter referred to as "slurry") in which an abrasive grain is dispersed in the form of slurry in a method of polishing by combining a chemical action by the processing liquid and a mechanical action by an abrasive grain.

The polishing device for use in the CMP method is mainly comprises a platen, a wafer carrier head, a slurry supply nozzle, and a dresser. The polishing pad is stuck on said platen, and the wafer for creating a semiconductor integrated circuit is attached to the wafer carrier head. A polishing step by the CMP method is performed by pressing the surface to be polished of the wafer attached to the wafer carrier head against the polishing surface of the polishing pad, simultaneously rotating the platen and said wafer carrier head and, sandwiching the slurry supplied on the polishing surface between the surface to be polished and the polishing surface.

During or prior to the polishing step, conditioning of the

/3

polishing pad usually is performed with a dresser in which a diamond has been affixed. When it is performed during the polishing step, the conditioning treatment removes the surface layer of the polishing surface of the polishing pad, thereby

removing polishing crumbles, and thus plays a role of reviving the clean surface of the polishing pad. Also when it is performed prior to the polishing step, the conditioning treatment also plays a role of forming fine texture (in an order of a few μm) useful in transporting the slurry on the surface layer of the polishing side.

Though the slurry may vary depending on the material to be polished and the process, it generally comprises 100 - 80 wt% of a processing liquid which is a solution of an oxidizing agent and a solubilizing agent such as hydrogen peroxide (H_2O_2) and ferric nitrate ($Fe(NO_3)_3$), and 0 - 20 wt% of an abrasive grain such as silica (SiO_2), ceria (CeO_2), and alumina (Al_2O_3). In the polishing step using a slurry, a chemical polishing action by dissolution, embrittlement, or the like with the oxidizing agent, the solubilizing agent, or the like in the processing liquid and a physical polishing action by the abrasive grain takes place simultaneously.

In the polishing step by the CMP method, the first requirement for the polishing pad is a high polishing speed. In order to obtain a high polishing speed, the polishing surface of the polishing pad must have a structure that permits an efficient transport and retention of the slurry supplied from the slurry supply nozzle to the polishing surface along the entire surface of the contact interface between the polishing

surface of the polishing pad and the surface to be polished of the wafer, and permits discharge of a polished product or pad crumble generated at the polishing area. For this purpose, the polishing pad used in a conventional method has a concave-convex structure (in an order of a few hundred μm) such as a concentric or spiral groove or the like on the entire pad surface as well as a local concave-convex structure (in an order of a few dozen μm) such as an air bubble resulting from the production process.

The second requirement is the long life of the polishing pad, i.e. a large number of wafers can be polished without replacing the polishing pad. For this purpose, a material that constitutes the polishing pad must have high abrasion resistance.

The third requirement is a high planarizing ability. Particularly, since a copper wiring having a thickness of 1,000 nm or greater must be polished in the polishing process of copper-plated wiring in damascene wiring, a high planarizing ability is required so as to offset a non planar part copied onto the plating surface from a trench in the plating process. In the polishing of a surface to be polished comprising a different material such as copper, an interlayer insulation film, and a barrier metal, non planarizing such as

/4

dishing and erosion tends to occur, and thus it is necessary to minimize non planarizing by using a polishing pad that is highly

uniform itself, wherein a polishing surface has an anti-deformation property.

A conventionally known polishing pad for CMP may be divided into a polishing pad that utilizes a resin having a closed cell structure, a polishing pad that utilizes a resin having an open cell structure, a polishing pad that utilizes a resin having a nonporous structure or a two-layered polishing pad comprising these that are stuck to each other.

As the polishing pad that utilizes a resin having a closed cell structure, a polishing pad comprising foaming polyurethane is known. Said polishing pad is produced in a process in which a block-like urethane foam is produced in a batch type reaction and then said block-like foam is sliced into a sheet form. Since said polishing pad has a hemispheric recess (in an order of few dozen μm) derived from a sliced air bubble as a local concave-convex structure, it is usually used with a concave-convex structure covering the entire surface of the pad such as a groove or the like formed by a cutting operation.

However, since it is difficult to secure uniformity in a reaction temperature and uniformity in a foaming factor throughout the entire reaction vessel in the production of said polishing pad, it is difficult to produce a product that is uniform throughout the polishing pad. Also since a slurry component or a product generated during polishing tends to

precipitate in the above hemispheric recess in said pad, it has a drawback of clogging in a relatively short period of time. Thus, in order to maintain a high polishing speed, it is necessary to frequently remove a clogged part on the surface of the polishing pad with the dresser. Thus, it has problems in that a total of long dressing time during polishing is required and that the polishing pad has a short life. That is, the polishing pad comprising such a polyurethane foam has not always satisfied the above three requirements for the polishing pad (i.e., a high polishing speed, abrasion resistance, and planarizing ability).

A representative polishing pad that uses a resin having an open cell structure is a polishing pad in which polyurethane has been impregnated into a polyester felt fiber sheet (see U.S. Patent No. 4,927,432). Said polishing pad is produced in a process in which a thermo-curing polyurethane dissolved in a solvent such as dimethylformamide, methylethyl ketone, and tetrahydrofuran is impregnated into a felt fiber sheet,

/5

and after evaporating the solvent by drying, the polyurethane is cured by heat. Said polishing pad has a continuous air bubble (in an order of few dozen to 200 μm) derived from the felt as a local concave-convex structure. It can also be used without forming a groove or the like on the entire surface of the pad,

since the slurry is transported via a mechanism in which it soaks into the entire polishing pad through said continuous air bubble and soaks out by the pressure on the polished surface.

However, the process of producing said polishing pad mainly comprises a drying step and a heat reaction step, and the reaction mixture is at a state in which it tends to aggregate, and thus it is difficult to maintain the composition and physical property of the polishing pad material uniformly on a microscopic level. Furthermore, since it has compressibility derived from the open cell structure, it has a problem of poor planarizing ability. Furthermore, due to the presence of space between fibers in a felt sheet as a continuous air bubble, a polishing crumble generated in wafer polishing becomes tangled with said fiber and thereby a scratch may often appear in a polished product. Therefore, in the polishing pad in which polyurethane has been impregnated into a polyester felt fiber sheet, a satisfactory result has not been obtained in terms of the polishing speed and the planarizing ability.

As a polishing pad using a resin having a nonporous structure, a solid homogeneous polymer such as polyurethane was proposed (see U.S. Patent No. 5,489,233). Also, there was proposed a polishing pad using a resin having a nonporous structure created with a light-curing resin using a polyurethane polymer (see U.S. Patent No. 5,965,460). Unlike the above two

polishing pads, said polishing pad has no essential concave-convex structure, and thus it is necessary to create a local concave-convex structure (texture: in an order of a few μm) by conditioning treatment or the like. Also, when the polishing pad is used, a concave-convex structure (in an order of a few hundred μm) covering the entire pad such as a groove or the like may be formed by a cutting operation. In the case of the above polishing pad using a resin having a nonporous structure created with a light-curing resin, the concave-convex structure such as a groove or the like can also be created by the photolithography method.

However, the above polishing pad using a resin having a nonporous structure only has a concave-convex on the surface

/6

thereof by conditioning treatment or the like, and thus it has a problem in that it does not have a sufficient ability to retain the slurry and has a low polishing speed. Besides, it has a problem in that the life of the polishing pad is short.

It has also been proposed that in order to form a concave-convex on the surface of the above polishing pad using a resin having a nonporous structure thereby to enhance the ability of retaining the slurry, a polymer filler, alumina, silica, a hollow ceramic balloon, a hollow glass bead, or the like can be added to the light-curing resin which the polishing pad is

comprised of (see U.S. Patent No. 6,036,579). However, even if a filler is added to the resin, each filler is independently dispersed in the polishing pad and removed from the polishing surface by polishing, and thus it has little effect of enhancing abrasion resistance of the polishing surface and the extended life of the polishing pad cannot be expected. Thus, although a drawback resulting from the production process of a polishing pad using a resin having a closed or open cell structure can be eliminated by the polishing pad using a resin having a nonporous structure, the above three requirements for the polishing pad could not be satisfied at the same time. That is, with the polishing pad using a resin having a nonporous structure, uniformity as a whole can be obtained which contributes to the planarizing ability, it was not satisfactory in terms of high polishing speed (ability of transporting and retaining the slurry) or abrasion resistance.

[Disclosure of the Invention]

The present invention provides a polishing pad that has a higher polishing speed than the conventional polishing pad, higher uniformity in polishing, and a longer life (i.e., a polishing pad is provided that simultaneously satisfies the above three requirements). Particularly, it provides a polishing pad having a high planarizing ability that is suitable for polishing of a thick conductor pattern such as a copper wiring

pattern, aluminum wiring pattern, or the like of the above damascene wiring. Furthermore, the present invention provides a method of polishing a wiring pattern comprising copper or aluminum formed on the surface of a wafer for creating a semiconductor integrated circuit using the above polishing pad. Furthermore, the present invention provides a method of producing the above polishing pad for use in polishing the surface of a wafer for creating a semiconductor integrated circuit.

That is, the first aspect of the present invention provides a polishing pad comprising fabric and a nonporous resin that fills the space between component fibers of the fabric.

In the polishing pad of the present invention, as the above fabric, a nonwoven fabric comprising as a component fiber at least one selected from the group consisting of a polyester fiber, an acrylic fiber,

/7

a polyamide fiber, silk, wool, and cellulose is preferably used. Furthermore, a fabric comprising a fiber that has a moisture content of 10% or greater at 21°C and 80% RH is preferably used. Furthermore, a fabric comprising a fiber having a tensile strength at dry of 3 g/D or greater is preferably used.

The above resin is preferably a light-curing resin that was produced by light-curing a photo-sensitive resin composition

containing at least one selected from the group consisting of a hydrophilic photopolymeric monomer, a hydrophilic photopolymeric polymer, and oligomer.

The second aspect of the present invention provides a method of polishing using a polishing pad comprising a nonporous light-curing resin reinforced with a fabric and the slurry.

According to the method of the present invention, as the above fabric, a fabric comprising a fiber that has a moisture content of 10% or greater at 21℃ and 80% RH, or a fabric comprising a fiber that has a tensile strength at dry of 3 g/D or greater is preferably used. Also, a fabric comprising a fiber with a sectional form having a shape irregularity ratio of 1.2 or greater is preferably used.

The third aspect of the present invention provides a method of producing a polishing pad, wherein a photo-sensitive resin composition is impregnated in a substrate comprising a fabric and then irradiated with an ultraviolet ray or a visible light, thereby curing the composition.

A polishing pad using a resin having a nonporous structure is preferred so as to offset heterogeneity in the size and density of an air bubble in the polishing pad that uses a resin having a foam structure of prior art and heterogeneity in polishing resulting from heterogeneity in compressibility associated thereto. However, even if a filler is put into the

polishing pad that uses a resin having a nonporous structure of prior art, the polishing speed was low and abrasion resistance was poor.

The present inventors have come up with an idea of combining a substrate comprising a fabric with a resin having a nonporous structure so as to resolve the above problems. U.S. Patent No. 5,489,233 that discloses the above polishing pad comprising a solid homogeneous polymer (a nonporous structure) describes that heterogeneity originally present in the bulk substance is not preferred to suppress a variation in polishing. Furthermore, U.S. Patent No. 6,036,579 that discloses the

/8

polishing pad comprising a light-curing resin (a nonporous structure) describes that preferably a filler is not added, and if added, a polymer filler or a particulate filler with a mean size of 1 - 1,000 nm can be added. Thus, although the addition of a fabric was totally unexpected in terms of securing transparency for "photosensitization" of a photo-sensitive resin composition according to these disclosures, the present inventors thought that the problem could be resolved by optimizing the reaction condition and the composition of the photo-sensitive resin used, and thereby completed the present invention.

[Most Preferable Embodiment for Implementing the Invention]

Below, the present invention will be explained in detail.

Figure 1 illustrates a cross section diagram of an embodiment of the polishing pad according to the present invention. Said diagram illustrates a cross section along the direction of thickness of the polishing pad, wherein 1 denotes the polishing surface and 2 denotes a groove (in an order of a few hundred μm) formed throughout the polishing pad. In the polishing step, the polishing surface 1 is pressed against the surface to be polished of the wafer. A groove 2 is a part for transporting the slurry to the entire area of the polishing surface. The polishing pad itself becomes abraded by wafer polishing, and when it is abraded until there is no groove 2 left, the transportation efficiency of the slurry decreases, and thus normally it is replaced with a new polishing pad before there is no groove 2 left.

The polishing pad of the present invention comprises a substrate comprising a fabric and a nonporous resin that fills the space between component fibers of the substrate.

Unlike a polishing pad that uses a resin having a closed cell structure or a polishing pad that uses a resin having an open cell structure, the polishing pad of the present invention is not porous and thus it does not develop heterogeneity in polishing resulting from a distribution of an air bubble and compressibility. Also, unlike a conventional polishing pad that

uses a resin having a nonporous structure, the polishing pad of the present invention uses a substrate comprising a fabric that is continuous throughout the polishing pad, thereby making the entire polishing pad a strong structure, which is capable of suppressing abrasion and increasing the number of wafers to be polished with one pad.

Furthermore, by using said substrate with a higher water absorption and/or combining the substrate with a light-curing resin having a high water absorption, it is possible to increase the ability of retaining the slurry used in the polishing step and the polishing speed. Particularly, when a slurry that performs polishing mainly by a chemical action as described below is used, such an enhanced water absorption exhibits an effect in retaining the slurry.

Also, the concave-convex structure (this concave-convex

/9

structure is derived from the structure of the fabric itself) in an order of few dozen μm on the surface of the fabric exposed on part of the polishing surface of the polishing pad contributes to the efficient transport and retention of the slurry, and thus enables to attain a high polishing speed. Particularly, when a slurry that performs polishing mainly by a mechanical action as described below is used, such an concave-convex structure exhibits an effect in retaining the slurry. Also by using the

concave-convex structure resulting from the structure of the fabric itself, it is possible to circumvent the problem such as the above clogging of an air bubble or scratch due to tangling of a polished crumble into a continuous air bubble.

The fabric for use as the substrate in the polishing pad of the present invention may be a woven or nonwoven fabric, but the nonwoven fabric is preferably used. As a method of making the nonwoven fabric, an immersion adhesion method, needle punch method, spun bond method, stitch bond method, a wet type water jet method, or the like is known. The fabric for use in the present invention is preferably the one that is highly dense and homogeneous so as to maintain a high and uniform polishing speed. An example of a preferred fabric is a nonwoven fabric produced by the water jet method. Also preferred is a nonwoven fabric that was created by another method and compressed by a press or the like to a high density.

As a component fiber of said substrate, a chemical synthetic fiber such as a polyester fiber, an acrylic fiber, a polyamide fiber, or the like and a natural fiber such as cellulose, wool, silk, or the like can be used. Among them, a fabric comprising a fiber having a high tensile strength, a fabric comprising a fiber having high hydrophilicity, or a nonwoven fabric comprising a porous, irregular shaped cross sectional, or ultra-thin fiber is preferably used. Particularly,

among these substrates, a nylon nonwoven fabric, rayon nonwoven fabric, and nonwoven fabric comprising a porous fiber are used more preferably in terms of the polishing speed.

As the slurry for polishing copper for use in the damascene wiring described above in the polishing method of the present invention, two types of slurries are preferably used: a slurry that uses aluminum oxide as an abrasive grain and polish mainly by a mechanical action, and a slurry that uses colloidal silica as an abrasive grain and polish mainly by a chemical action such as an oxidation reaction, complex formation, or the like. When a slurry that polishes mainly by a chemical action is used, it is also possible to obtain planarization of polishing, i.e. to minimize a dent, which is called dishing, in a copper wiring at the edge of a polished surface, or a dent, which is called

/10

erosion, at a part of high copper wiring density.

Particularly, among the substrates in the present invention, a fabric comprising a fiber having an excellent tensile strength exhibits an excellent polishing performance with a slurry that polishes mainly by a mechanical action. This is because, it is believed, the fiber itself partly protruding from the polishing surface (a concave-convex in an order of few dozen μm of the polishing surface as described above) functions as the polishing material and, since it hardly warps by a load, can effectively

press the abrasive grain against the polished surface. Particularly, a fiber having a tensile strength at dry of 3 g/D or greater is preferred, and a fiber having a tensile strength of 4.5 g/D or greater is more preferred. An example of such a fiber includes an acrylic fiber, a nylon fiber, or some of a polyester fiber. The tensile strength of a fiber can be determined based on the method of determination provided in JIS L1013 (test method of chemical fiber filaments).

Also, a fabric comprising a fiber having a high water absorption exhibits an excellent polishing performance with a slurry that mainly polishes by a chemical action. This is because, it is believed, the fiber exposed on part of the polishing surface sucks up the processing liquid of the slurry and supplies it to the surface to be polished. Particularly, a fiber having a moisture content of 10% or greater at a condition of 21°C and 80% RH is preferred, and a fiber having a moisture content of 15% or greater is more preferred. An example of such a fiber includes a cellulose fiber such as rayon or the like. The moisture content of a fiber can be determined based on the method of determination provided in JIS L1013 (test method of chemical fiber filaments).

Even if a fiber having a moisture content of less than 10% at a condition of 21°C and 80% RH is used, a polishing pad that uses a fabric comprising a porous fiber having a hole in a cross

section or a fiber having a notch or gap on the surface exhibits an excellent polishing ability with a slurry that mainly polishes by a chemical action. This is because, it is believed, a fiber exposed on the polishing surface is crushed into a small piece due to the conditioning treatment or a load by the wafer, sucking up the processing liquid of slurry, or serving as a place to capture an abrasive grain. A similar effect can be expected when a fabric comprising a fiber with an irregular shaped cross section having a large surface area instead of a circular cross section is used.

A degree of shape irregularity is defined by the shape irregularity ratio determined by the following method. First, a fabric is cut with a cutter so as to expose the cross section of the fiber. Then, a photograph of the cross section is taken

/11

using an optical microscope or an electron microscope. From the photograph of the cross section, the length S of the periphery of the cross section of one fiber constituting the fabric is determined (when the cross section of the fiber has one or more holes, the sum of periphery length of each hole is added to S). One half of the mean of the maximum and the minimum of a line segment cut out by the periphery of said cross section when a plurality of straight lines that cross the center of gravity of the fiber's cross section are drawn is set as a virtual radius a.

The radius of a circle whose length of outer periphery is S is set as b (b can be determined by $b=S/2\pi$). Though the shape of each fiber constituting the fabric has a similar tendency, they are slightly different from each other, and thus, after selecting five arbitrary fibers from the photograph of the above cross section, b/a is calculated for each fiber and the mean thereof is determined. This value is defined as the shape irregularity ratio. When the shape irregularity ratio is greater than 1, the fiber has an irregular shape, and according to the present invention, a fabric comprised of a fiber having a shape irregularity ratio of 1.2 or greater is preferred, and that having a shape irregularity ratio of 1.4 or greater is more preferred.

Since the above substrate (fabric) is impregnated with a photo-sensitive resin composition and then irradiated with an ultraviolet ray or a visible light to cure said resin composition, the substrate, even if it is opaque per se, can be used in the present invention if the transparency can sufficiently trigger a light-curing reaction is obtained at a state in which a photo-sensitive resin composition is impregnated thereinto.

The resin for use in the present invention is required to be a nonporous resin, and preferably a nonporous light-curing resin (obtained by light-curing a photo-sensitive resin

composition). When a thermosetting resin is used to produce the nonporous polishing pad of the present invention, a polishing pad may sometimes warp due to post-setting residual stress derived from heat distribution or the like. In contrast, when a light-curing resin is used, the problem of warping seldom develops because the light-curing reaction of a photo-sensitive resin composition proceeds in a short period of time as compared to the thermosetting. Furthermore, since the reaction proceeds more uniformly as compared to the thermosetting, the light-curing resin, which is a reaction product, has consequently a more homogeneous composition than the thermosetting resin.

In the CMP process, the amount of polishing is monitored by an optical method, and thus an opening is sometimes made at part of the polishing surface of the polishing pad to insert a transparent member (hereinafter referred to as window) (for example, see for U.S. Patent No. 5,893,796). When a fabric and a light-curing resin which are a preferred embodiment of the present invention are used, the process of producing a polishing pad having the above window can be simplified. That is, a photo-sensitive resin composition is impregnated into a fabric in

/12

which the part corresponding to the opening was cut, and cured by light irradiation so that said window can be formed within the polishing pad.

Said light-curing resin was cured by irradiating a photo-sensitive resin composition with an ultraviolet ray or a visible light, and said photo-sensitive resin composition contains at least one of a photo polymerizing polymer or oligomer and a photo polymerizing monomer. According to the present invention, it is preferred to use a photo-sensitive resin composition containing at least one of a hydrophilic photo polymerizing polymer, oligomer, or hydrophilic photo polymerizing monomer so as to enhance water absorption rate of the pad.

Said photo polymerizing polymer or oligomer includes an unsaturated polyester, polyether(meth)acrylate, polyester(meth)acrylate, polybutadiene(meth)acrylate, polyepoxy(meth)acrylate, or the like.

Particularly, as a constituent component of the photo-sensitive resin composition, so as to obtain a light-curing resin having a high water absorption, the one having a hydroxyl group, carboxyl group, or phosphate group at the end or at the side chain is preferred. The above includes, for example, the one having a hydroxyl group or carboxyl group at the end or at the side chain of the polymer chain like an unsaturated polyester, or a polymer or oligomer in which a monoisocyanate having an ethylenic unsaturated group was bound to a hydroxyl group of an unsaturated polyester polymer leaving only the carboxyl group.

As the above photo polymerizing monomer, a compound having at least one ethylenic unsaturated group at the end or at the side chain is preferred. The ethylenic unsaturated group refers to the one included in acrylate, methacrylate, vinyl, allyl, or the like. Specifically, the above includes the following: a compound having one of various ethylenic unsaturated groups such as lauryl methacrylate, N-(3-dimetylaminopropyl) (meth)acrylamide, hydroxyethyl(meth)acrylate, hydroxypropyl(meth)acrylate, ethyl(meth)acrylate, propyl(meth)acrylate or the like, and a multifunctional monomer such as ethyleneglycol di(meth)acrylate, diethyleneglycol di(meth)acrylate, 1,4-butandiol di(meth)acrylate, 1,6-hexanediol di(meth)acrylate, trimethylolpropane tri(meth)acrylate, glycerin di(meth)acrylate, triethyleneglycol di(meth)acrylate,

/13

polyethylene glycol #200 di(meth)acrylate, polyethylene glycol #400 di(meth)acrylate, 1,3-butanediol di(meth)acrylate, neopentylglycol di(meth)acrylate, 1,10-decanediol di(meth)acrylate, di(meth)acrylate of ethylene oxide adducts of bisphenol A, triallyl isocyanurate, isocyanuric acid ethylene oxide-modified di(meth)acrylate, isocyanuric acid ethylene oxide-modified tri(meth)acrylate, ethylene oxide-modified trimethylolpropane tri(meth)acrylate, pentaerythritol tri(meth)acrylate, pentaerythritol tetra(meth)acrylate,

dipentaerythritol hexa(meth)acrylate, 1,9-nonanediol di(meth)acrylate, tri(meth)acrylate of three molar ethyleneoxide adducts of pentaerythritol, oligopropyleneglycol di(meth)acrylate, and polytetramethyleneglycol di(meth)acrylate.

In order to enhance the water absorption of the light-curing resin, alkyleneglycolic and alykyleneethereal monomers or a photo polymerizing monomer containing the hydroxyl group in the molecule are particularly preferred among these photo polymerizing monomers.

Also preferred is a photo polymerizing monomer containing an urethane group in the molecule that is obtained by reacting hydroxy(meth)acrylates such as pentaerythritol tri(meth)acrylate, 2-hydroxyethyl(meth)acrylate, 2-hydroxypropyl(meth)acrylate and 2-hydroxybutyl(meth)acrylate with monoisocyanate.

A photo polymerizing monomer containing an urethane group in the molecule obtained by reacting a hydroxyl group-containing compound with monoisocyanate having an ethylenic unsaturated group is also preferred.

A specific example includes the following: a photo polymerizing monomer that is obtained by reacting a hydroxyl group-containing compound with monoisocyanate having an ethylenic unsaturated group, said hydroxyl group-containing compound including polyether polyols such as poly(oxypropylene)polyol, copoly(oxyethylene-oxypropylene)diol,

and polytetramethyleneetherdiol, polyester polyols such as polyester polyol, polycaprolactone polyol and polycarbonate

/14

polyol, straight-chain polyols such as 1,4-butanediol, 1,5-pentanediol, 1,6-hexanediol and polybutadine polyol, trimethylol propane, neopentyl glycol, methylpentane diol, acryl polyol, phenol resin polyol, epoxypolyol, polyester-polyether polyol, acryl, styrene, vinyl added and/or dispersed polyether polyols, carbonate polyol, ethylene glycol, diethylene glycol, propylene glycol, dipropylene glycol, caprolactone diol, hydroxyethoxylated bisphenol A, hydroxyethoxylated bisphenol S, a monofunctional alcohol, and saturated and unsaturated polyester.

Also, any one or a combination of a plurality of these hydroxyl group-containing compounds may be used. A diamine such as 3,3-dichloro-4,4-diaminophenylmethane may also be used in combination with these hydroxyl group-containing compounds. Said hydroxyl group-containing compound preferably has a plurality of hydroxyl groups in the molecule.

As the above monoisocyanate, 2-isocyanate ethylmethacrylate, phenyl isocyanate, 3-isocyanate propyl triethoxysilane, or the like is preferred. Among them, 2-isocyanate ethylmethacrylate has an ethylenic unsatuated group that functions as a binding point for light-curing or thermosetting, and by adjusting the

ratio of mixing 2-isocyanate ethylmethacrylate with other monoisocyanates having no ethylenic unsatuated group, the hardness of the polishing pad can be controlled.

In contrast, when a monoisocyanate obtained by reacting an isocyanate group at one end of diisocyanate with a hydroxyl group-containing compound is used, an aggregation of resin after light-curing becomes large and thus it is not preferred. This means there is a higher probability that, when used in polishing, a polishing crumble with a large diameter tends to be formed and thus may cause a scratch on an object to be polished.

In a photo-sensitive resin composition for use in the present invention, preferably 80 – 5 wt% of a photo polymerizing monomer is blended with 20 – 95 wt% of a photo polymerizing polymer or oligomer. More preferably, 70 – 20 wt% of a photo polymerizing monomer is blended with 30 – 80 wt% of a photo polymerizing polymer or oligomer. Particularly, it is preferred that an alkyleneglycolic, an alkylene ethereal, or a hydrophilic photo polymerizing polymer or oligomer or a hydrophilic photo polymerizing monomer containing at least one of a hydroxyl group, carboxyl group, or phosphate group in the molecule is blended to 20 wt% or greater.

The photo-sensitive resin composition in the present invention usually is used with an addition of a photo

polymerization initiator. Said photo polymerization initiator includes benzophenones, acetophenones, α -diketones, acyloins, acyloinethers, benzylalkylketals, polynuclear quinones, thioxanthones, acylphosphines, and the like. Specifically preferred is benzophenone, chlorobenzophenone, acetophenone, benzyl, diacetyl, benzoin, pivaloin, benzoinmethylether, benzoinethylether, benzyldiethylketal, benzyldiisopropylketal, anthraquinone, 1,4-naphthoquinone, 2-chloroanthraquinone, thioxanthone, 2-chlorothioxanthone, acylphosphineoxide, or the like. They may be used alone or in combination.

The photo polymerization initiator may preferably be used at 1 - 20 weight parts relative to 100 weight parts of the sum of the above photo polymerizing polymer or oligomer and a photo polymerizing monomer. According to the present invention, the presence of a fabric reduces light transmission and thus it is preferred to use a photoinitiator having high photo-sensitivity. Furthermore, other additives may be added to said photo-sensitive resin composition as appropriate as long as it does not damage the effect of the present invention.

The polishing pad of the present invention may be obtained by impregnating said fabric with the above photo-sensitive resin composition by coating or dipping, and then irradiating an ultraviolet ray or a visible light of a wavelength corresponding

to the photo-sensitivity of said resin composition so as to cure said resin composition, thereby forming a light-curing resin.

The nonporous resin in the polishing pad of the present invention means a resin having a porosity of 10% or less. The porosity is defined as follows. From an object for which the porosity is to be measured,

/16

ten samplings are performed, and a sample section is sliced to expose a cross section, of which a photograph is taken by an optical microscope or an electron microscope at a magnification of 60. The ratio of an area of a hole relative to a cross section area of the sliced sample section of 1 mm long and 1 mm wide is determined by image processing or the like, and the mean of ten determinations is defined as a porosity. Herein, when the polishing pad is composed of a fabric part and a resin part as in the present invention, the porosity of the polishing pad means a porosity calculated based on the part excluding the fabric in the polishing pad [the area of a hole/the area of the part excluding the fabric in the polishing pad (the area of the resin + the area of the hole)]. The resin for use in the polishing pad of the present invention is nonporous, and even if an air bubble that entered during the impregnation process into a fabric is present, the porosity of the polishing pad is 10% or less. In order to maintain uniformity in the polishing speed and

polishing, the porosity of the polishing pad is preferably 5% or less, and more preferably 2% or less.

Since the polishing pad of the present invention uses a nonporous resin as described above, the slurry cannot be retained and transported via a continuous air bubble unlike the polishing pad of the prior art that uses a resin having an open cell structure. However, by using a fabric as the substrate, it can have an ability of efficiently retaining and transporting a slurry on the surface of the wafer. That is, as described above, whether a slurry that polishes mainly by a chemical action is used, or a slurry that polishes mainly by a mechanical action is used, it is possible to efficiently retain and transport the slurry on the surface of the wafer depending on the characteristics or structure of the fabric. Furthermore, a fabric as the substrate is subjected to polishing at a state in which most portions excluding the part exposed on the polishing surface are embedded in the resin, thereby minimizing a raising on the polishing surface. Therefore, it is possible to accomplish the basic requirement of the CMP polishing pad of selectively polishing and planarizing a protruding portion on the surface of the wafer.

The ratio of the fabric and the resin in the polishing pad of the present invention is established so that the ratio of the area of the fabric as defined below comprises preferably 5 - 80%,

and more preferably 10 - 60% depending on the type of the resin and the type and structure of the fabric. From the part to be used in the polishing of the polishing pad, ten samplings are performed. The sample sections are sliced to expose a cross section, of which a photograph is taken by an optical microscope or an electron microscope at a magnification of 60.

/17

The ratio (%) of an area of the fabric relative to a cross section area of the pad of 1 mm long and 1 mm wide is determined by image processing or the like, and the mean of the ten determinations is defined as an area ratio of the fabric.

When a fiber of the fabric used as the substrate is thin, the fabric has a low density and the area ratio of the fabric is less than 5%, a sufficient polishing speed cannot be obtained and hence it is not preferred. When the area ratio of the fabric exceeds 80%, the impregnation of the resin becomes difficult and thus a nonporous resin having a low porosity cannot be obtained, which is not preferred.

In a preferred embodiment of the polishing pad of the present invention, by using a light-curing resin having a high water absorption and/or a fabric having a high water absorption (particularly it becomes necessary when a slurry that polishes mainly by a chemical action is used), as described above, the water absorption of the part used for polishing becomes high,

hence resulting in an enhanced ability of retaining the slurry. The water absorption of the polishing pad in a preferred embodiment of the present invention is 1 - 15%, more preferably 2 - 10%, and even more preferably 4 - 10%. For the polishing pad having a water absorption of 1% or less, the ability of retaining the slurry becomes insufficient and thus a sufficient polishing performance cannot be obtained. At a water absorption of 15% or greater, the strength of the polishing pad decreases, which may cause an inconvenience such as a reduced ability of planarizing and a quickened abrasion of the polishing pad. Herein, the water absorption is determined as follows. That is, (1) both sides of the pad are cut to expose the fabric on the surface to prepare a test sample. (2) The above sample is dried under vacuum at 50°C for 1 hour, and then the weight (A) is measured. (3) After soaking the sample in water at 23°C for 24 hours to impregnate the sample with water, the surface of said sample is wiped to remove a water drop, and the weight (B) is measured. (4) The water absorption of the sample is determined based on the water absorption={(B - A)/A} x 100(%).

On the polishing pad obtained as described above, a groove 2 is formed on the polishing surface by cutting as shown in Figure 1. The representative groove is about 200 - 1000 µm deep and about 100 - 500 µm wide, and have a groove-to-groove pitch of about 1 - 5 mm.

In performing polishing of the wafer using the polishing pad of the present invention, first a groove is formed on the polishing pad, which is then stuck on the platen of the CMP polishing device. Then, the surface of the polishing surface is subjected to conditioning treatment (formation of fine texture) with a dresser, and the fiber constituting the fabric is simultaneously exposed on the surface. On the other hand, the wafer is mounted to the wafer carrier head. Polishing is performed by supplying the slurry from the slurry supply nozzle to the polishing surface at a state in which the wafer is pressed against the polishing pad while rotating the wafer carrier head and the platen.

/18

When a slurry that polishes mainly by a chemical action is used at this time, a fabric comprising a fiber having a high moisture content or a fabric comprising a fiber having a high shape irregularity ratio is preferably used to obtain a high polishing speed. Furthermore, a slurry that polishes mainly by a mechanical action is used, a fabric comprising a fiber having a high tensile strength at dry is preferably used to obtain a high polishing speed as described above.

When the polishing speed becomes slow, the polishing surface is subjected to conditioning treatment to expose a fresh polishing surface to be used. Since the polishing surface

becomes abraded by the polishing process and the conditioning treatment, it should be replaced with a new one before the remaining part of the above groove disappears.

Herein, another material can be stuck on one side of the polishing pad of the present invention as needed, and can be used as a double-layer polishing pad. At this time, the effect of the present invention can be obtained by using the side of the polishing pad of the present invention as the polishing surface.

[Brief Explanation of the Figures]

Figure 1 is a cross section diagram of an embodiment of the polishing pad according to the present invention.

[Embodiments]

Below the present invention will be specifically explained by the embodiment, however, the present invention is not limited to these embodiments in any way.

[Embodiment 1]

A fabric comprising a nonwoven fabric ("Shaleria" manufactured by Asahikasei K. K.) with a thickness of 1 mm comprising a porous acrylic fiber having a tensile strength at dry of 3.1 g/D, a shape irregularity ratio of 1.5 and a moisture content of 1.2% was impregnated with a photo-sensitive resin composition comprising an unsaturated polyester oligomer 65 wt%, a hydroxyl group-containing monofunctional monomer 17 wt%,

another monomer 16 wt% and a photo polymerization initiator 2 wt%, and then an ultraviolet ray was irradiated from both sides to prepare a polishing pad with a thickness of 1.5 mm and a diameter of 50 cm. The area ratio of the fabric of 35%, a water absorption of 5.6% and a porosity (a value calculated for the part excluding the fabric in the polishing pad) of 2.0%.

After creating a groove for slurry transport by machining, the polishing pad was mounted to the CMP polisher, and the mean polishing speed of the copper film on the silicon wafer was determined using a slurry of alumina abrasive grain to obtain a polishing speed of 520 nm/min at the maximum.

/19

Also, the amount of abrasion of the pad was determined to be 0.5 μm/min under a dress condition of 100-grid diamond size.

[Embodiment 2]

A fabric comprising a nonwoven fabric ("ColdonR0260T" manufactured by Asahikasei K. K.) with a thickness of 1 mm comprising a rayon fiber having a tensile strength at dry of 2.1 g/D, a shape irregularity ratio of 1.2 and a moisture content of 21.3% was impregnated with a photo-sensitive resin composition as in Embodiment 1, and then an ultraviolet ray was irradiated from both sides to prepare a polishing pad with a thickness of 1.5 mm and a diameter of 50 cm. The area ratio of the fabric of 13%, a water absorption of 7.3% and a porosity (a value

calculated for the part excluding the fabric in the polishing pad) of 0.1% or less.

After creating a groove for slurry transport by machining, the polishing pad was mounted to the CMP polisher, and the mean polishing speed of the copper film on the silicon wafer was determined using a slurry of silica abrasive grain to obtain a polishing speed of 660 nm/min at the maximum. Also, the amount of abrasion of the pad was determined to be 0.5 μm/min under a dress condition of 100-grid diamond size.

[Embodiment 3]

A photo-sensitive resin composition was prepared in the following step.

(A) To an unsaturated polyester with a molecular weight of 2,400 that was synthesized by a usual polycondensation reaction at a ratio of one mole part of diethylene glycol, 0.5 mole part of adipic acid, and 0.5 mole part of fumaric acid, di-N-butyltin laurate was added as an urethanation catalyst, and then 6.3% of 2-isocyanatoethyl methacrylate at a weight ratio to the above polyester was added in a drop under stirring to perform urethanation treatment. The above urethanation catalyst was added to 5% in a weight ratio to 2-isocyanatoethyl methacrylate.

(B) To 3-methyl-1,5-pentanediol, di-N-butyltin laurate was added as an urethanation catalyst, and then two mole parts (2.6-fold amount on a weight ratio) of 2-isocyanatoethyl methacrylate

to one mole part of the above diol were added in a drop under stirring to perform urethanation treatment. The above urethanation catalyst was added to 5% in a weight ratio to 2-isocyanatoethyl methacrylate.

(C) To caprolactone diol, di-N-butyltin laurate was added as an urethanation catalyst, and then two mole parts (0.56-fold amount on a weight ratio) of 2-isocyanatoethyl methacrylate to one mole part of the above diol were added in a drop to perform urethanation treatment. The above urethanation catalyst was added to 5% in a weight ratio to 2-isocyanatoethyl methacrylate.

After the reactions, the urethanated products (A), (B), and (C), and (D) triallyl isocyanurate were mixed at a weight ratio of 1/1/1/0.2, to which were added 2,2-dimethoxy-2-phenylacetophenone as a photopolymerization initiator and 2,6-di-tert-butyl-4-methylphenol as a polymerization inhibitor at a weight ratio of 2% and 0.038%, respectively, relative to the total amount of (A), (B), (C), and (D) to prepare a sticky photo-sensitive resin composition.

A fabric comprising a nonwoven fabric ("ColdonL0170T" manufactured by Asahikasei K. K.) with a thickness of 0.6 mm comprising a nylon fiber having a tensile strength at dry of 4.9 g/D, a shape irregularity ratio of 1.0 and a moisture content of 5.2%, and an acrylic fiber nonwoven fabric ("Shaleria"

manufactured by Asahikasei K. K.) with a thickness of 0.6 mm that were overlaid and pressed was impregnated with a photo-sensitive resin composition prepared in the above step, and then an ultraviolet ray was irradiated from both sides to prepare a polishing pad with a thickness of 1.5 mm and a diameter of 50 cm by the UV crosslinking method.

With the side of the nylon fiber nonwoven fabric as the polishing surface, the part used for polishing of the fabric had an area ratio of the fabric of 42%, water absorption of 2.1% and a porosity (a value calculated for the part excluding the fabric in the polishing pad) of 1.3%. After creating a groove for slurry transport by machining, the polishing pad was mounted to the CMP polisher, and the mean polishing speed of the copper film on the silicon wafer was determined using a slurry of alumina abrasive grain as in Embodiment 1 to obtain a polishing speed of 640 nm/min at the maximum. Also, the amount of abrasion of the pad was determined to be 0.1 μm/min under a dress condition of 100-grid diamond size.

[Comparison Example 1]

Under the same condition as in Embodiment 1, except that the photo-sensitive resin composition was used alone without a fabric, a polishing pad having a thickness of 1.5 mm and a diameter of 50 cm was prepared in which a groove for slurry

transport was created on the polishing surface. The water absorption of said light-curing resin was 3.0%.

/21

The mean polishing speed of the wafer which was determined under the same condition as in Embodiment 1 was 250 nm/min. The amount of abrasion of the pad which was determined under the same dress condition as in Embodiment 1 was 3 µm/min.

[Comparison Example 2]

Under the same condition as in Embodiment 1, except that a urea filler was mixed instead of a substrate comprising a fabric, a polishing pad having a thickness of 1.5 mm and a diameter of 50 cm was prepared in which a groove for slurry transport was created on the polishing surface.

The mean polishing speed of the copper film on the wafer which was determined under the same condition as in Embodiment 1 was 210 nm/min. The amount of abrasion of the pad which was determined under the same dress condition as in Embodiment 1 was 3 µm/min.

[Comparison Example 3]

Using a polishing pad comprising a resin having a porosity (a value calculated for the part excluding the fabric in the polishing pad) of 75% having an open cell structure in which a felt comprising a polyester fiber was impregnated with a urethane elastomer, the mean polishing speed of the wafer was

measured under the same condition as in Embodiment 1, which was found to be 240 nm/min.

[Comparison Example 4]

Under the polishing condition using a silica slurry as in Embodiment 2 except that a rayon fiber nonwoven fabric ("ColdonR0260T" manufactured by Asahikasei K. K.) was used alone as a polishing pad without being impregnated with a photo-sensitive resin composition and except that a groove for slurry transport was not created, the mean polishing speed of the copper film on the wafer which was determined was found to be 320 nm/min.

/22

[Industrial Applicability]

The present invention provides a polishing pad having an excellent abrasion resistance, polishing speed, and uniformity in polishing, and thus time required in the polishing step of wafers for creating a semiconductor integrated circuit can be significantly shortened.

Also the present invention can provide a polishing pad that can be preferably used when a planarization property such as STI (Shallow Trench Isolation) is required, even for a wiring (for example, a thick conductor pattern such as a copper wiring pattern and aluminum wiring pattern of damascene wiring) containing copper or aluminum formed on the surface of a wafer

for creating a semiconductor integrated circuit or insulator pattern of silicon dioxide or the like.

/23

[Claims]

[Claim 1]

A polishing pad for use in surface polishing of a wafer for creating a semiconductor integrated circuit, comprising a fabric and a nonporous resin that fills the space between component fibers of the fabric.

[Claim 2]

The polishing pad in Claim 1, wherein the polishing pad is a nonwoven fabric comprising as a component fiber at least one selected from a group consisting of a polyester fiber, an acrylic fiber, a polyamide fiber, silk, wool, and cellulose.

[Claim 3]

The polishing pad in Claim 1 or 2, wherein the above resin is a light-curing resin that was obtained by light-curing a photo-sensitive resin composition containing at least one selected from the group consisting of a hydrophilic photopolymeric monomer, a hydrophilic photopolymeric polymer, and oligomer.

[Claim 4]

The polishing pad in Claim 2 or 3, wherein a fabric comprising a fiber that has a moisture content of 10% or greater at 21°C and 80% RH is used.

[Claim 5]

The polishing pad in Claim 2 or 3, wherein a fabric comprising a fiber having a tensile strength at dry of 3 g/D or greater is used.

[Claim 6]

A method of polishing a wiring containing copper or aluminum formed on the surface of a wafer for creating a semiconductor integrated circuit, wherein said polishing is performed by using a polishing pad comprising a fabric and a nonporous light-curing resin that fills the space between component fibers of the fabric and a slurry.

[Claim 7]

The method in Claim 6, wherein said fabric is a fabric comprising a fiber having a moisture content of 10% or greater at 21°C and 80% RH.

[Claim 8]

The method in Claim 6, wherein said fabric is a fabric comprising a fiber having a tensile strength at dry of 3 g/D or greater.

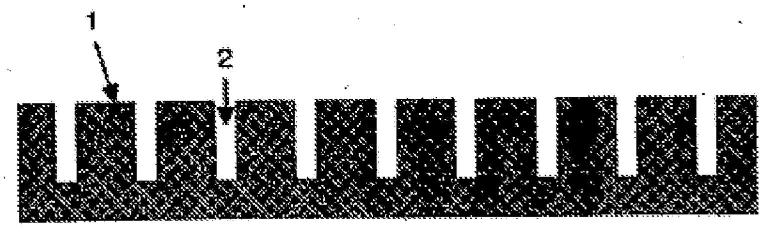
[Claim 9]

The method in Claim 6, wherein said fabric is a fabric comprising a fiber having a shape irregularity ratio of 1.2 or greater.

[Claim 10]

A method of producing a polishing pad for use in surface polishing of a wafer for creating a semiconductor integrated circuit, wherein said method comprises impregnating a substrate comprising a fabric with a photo-sensitive resin composition and then irradiating said resin composition with an ultraviolet ray or a visible light thereby to cure the composition.

Figure 1



[Translator's note]

P. 11/14 of 09-4853B is an English translation of P. 13/14 except for the very bottom right column for "Authorized Officer."

Name of the Officer: Tatsu Miyake [sealed]

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P. 12/14 is an English translation of P. 14/14.